# Integrating HACCP & TQM Reduces Pork Carcass Contamination

**Visual monitoring system combines Hazard Analysis Critical Control Point and Total Quality Management concepts to significantly reduce contamination and dramatically lower total bacterial count**

**Contamination by fecal or ingested matter is an unavoidable product of commercial operations during pork carcass processing. We tested the hypothesis that contamination rates could be minimized by a simple on-line visual monitoring system, operated primarily by the workers in the dressing area.**

With the aid of electronic capture and display, specific contamination events were attributed to a particular unit operation, thus allowing corrective action to be taken. The system integrated Total Quality Management (TQM) with Hazard Analysis Critical Control Point (HACCP) principles. Carcass contamination levels were reduced from approximately 8% to 1% over four years of operation of the system. Total aerobic plate counts fell a concomitant 99.8%. The on-line monitoring system has demonstrated a link between decreased fecal contamination levels and reduced total bacteria. More important, its use by pork processors may yield a reduction in fecal indicator organisms and potential pathogens, which may reduce risks to consumers.

**Fig. 1—Pork carcass processing** using a HACCP/TQM-based visual monitoring system lowers total bacterial count

HACCP systems currently provide the most effective means for minimizing microbial contamination on meat carcasses, thus decreasing the risk of foodborne illness to humans. To ensure proper functioning, on-line monitoring should be conducted around critical control points to ensure that hazards are reduced or eliminated. Monitoring must detect deviations from pre-established, acceptable criteria, while records should be maintained to document performance (Anonymous, 1991). At present, real-time microbiological monitoring is beyond current technology, so indirect measurements are necessary.

The U.S. Dept. of Agriculture's Food Safety & Inspection Service (FSIS) has implemented a food


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**Table 1 Slaughter and dressing operation and location of hardware components used for the on-line swine carcass fecal contamination monitoring system**

| Operation | Monitoring area | Monitoring system component and location | | | | |
|---|---|---|---|---|---|---|
| | | LED display | Pushbuttons | Photo eye | Computer | Controller/reset |
| Holding | | | | | | |
| Stunning | | | | | | |
| Bleeding | | | | | | |
| Scalding | | | | | | |
| Dehairing | | | | | | |
| Polishing | | | | | | |
| Singeing | | | | | | |
| Carcass washing | | | | | | |
| Head removal | | | | | | |
| Head inspection | | | | | | |
| Debunging | 1 | ✔ | | | | |
| Carcass opening | 2 | ✔ | | | | |
| Evisceration | 3 | ✔ | | | | |
| Carcass splitting | | | | | | |
| Trimming | | | ✔[a] | | | |
| Stamping | | | | | | |
| Weighing | | | | ✔ | | |
| Chilling | | | | | | |
| Electronic controlling | | | | | ✔ | ✔ |

[a]After trimming visible fecal contamination, the trimmer activates one of three pushbuttons (orange, yellow, blue) located at each trimming station, corresponding to monitoring areas 1, 2, and 3, respectively. This activates an short alarm, and a contamination event is displayed on the LED located in view of the operators (see Table 2)

safety standard which states that no visible fecal material can be present at the point of postmortem carcass inspection (FSIS, 1997). This standard is based on the realization that fecal material is a vehicle for bacterial pathogens. In pork slaughter establishments, this is accomplished by using sanitized knives to trim contaminated material prior to final carcass inspection. The trimming operation has been identified as a critical control point in a generic HACCP model for pork slaughter (FSIS, 1996a).

While slaughter establishments currently practice fecal contamination avoidance and removal techniques, integration of on-line monitoring, immediate feedback to operators engaged in evisceration, cumulative record keeping, and microbiological verification have not been reported. Such a system has the potential to ensure compliance with the FSIS standard, and to provide a format for continuous process improvement. This article describes an employee-run, electronic continuous monitoring system that has been successful in significantly reducing incidence of fecal contamination on pork carcasses.

## The Monitoring System

Hatfield Quality Meats, Hatfield, Pa., slaughters approximately 7,000 market-weight (100 kg average) pigs daily (Fig. 1). Specific dressing operations have been described previously (Borch et al., 1996; Miller et al., 1994, 1998) and are outlined in Table 1. The system, including the number of trimmers and the monitoring components, has the capacity to handle about 900 carcasses/hr.

The monitoring system mechanically consists of a controller (Mystic Model G4LC32, manufactured by OPT022 (Temecula, Calif.), a mainframe computer (Vax, Digital Electronic Corp., Maynard, Mass.), three color-coded pushbuttons, three key-operated reset switches, three LED display boards, and a photoelectric eye that increments to a counter.

Five trimmers serve as in-house carcass inspectors and are trained to detect and trim fecal and ingested matter. Each contamination event is attributed to three anatomical locations (ham/tenderloin, rib cage/leaf lard, and breast bone). The actual site of contamination on the carcass is assessed visually and is generally the size of a pea. Removal is accomplished by manually trimming the site and a 2- to 3-in radius from the site. In turn, each of the three anatomical locations is linked to a unit operation (Table 2).

By pressing a pushbutton, corresponding to an area of contamination on the carcass, the trimmers alert, by a loud alarm, the operators responsible for the contamination event. In addition, a score is registered against that operation on an LED display board located within the visual field of the operator. A photoelectric eye is used to tally a count of hogs for the entire day.

Four numbers—three from different areas of contamination and the total number of pigs—are uploaded from the controller to the mainframe computer four times daily, and the contamination numbers in the controller are reset. From these data, the percentage of contaminated carcasses is calculated and displayed, along with a statement indicating whether the percentage contamination is above or below the accepted level (Table 2).

Initially, tolerance levels were set at the average plus one standard deviation, so that as workers strove to decrease their respective scores and contamination rates declined, the tolerance level decreased accordingly. When a plateau was eventually reached and contamination rates leveled off, tolerance levels

**Table 2 Linkage between contamination location on carcasses and unit operation source, and maximum tolerance of contamination on pork carcasses prior to trimming**

| Anatomical location of contamination | Monitoring area | Unit operation likely to cause contamination | Pushbutton color at trimming stations |
|---|---|---|---|
| Ham/tenderloin | 1 | Debunging | Orange |
| Rib cage/leaf lard | 2 | Evisceration | Yellow |
| Breast bone | 3 | Carcass opening | Blue |

were set at the average plus two standard deviations. Two standard deviations were chosen as the tolerance levels after the plateau was attained to incorporate the lower averages achieved by improvements in the operation.

**Table 3 Causes of errors and corrective action taken if tolerances are exceeded**

| Contamination cause | Error | Corrective action |
|---|---|---|
| Personnel | Incorrect procedure | Review procedure<br>Replace/rotate employee<br>Adjust work environment |
| Equipment | Failure | Repair/adjust<br>Modify<br>Add equipment |
| Usual practices | Bloated intestine | Collect data linking contamination with gut fill<br>Interact with producer<br>Review transport practices |
| Other factors | Unforeseen | Appropriate to correct |

Data are reviewed by company management, and all tolerance breaches are investigated and solutions implemented. In general, problem areas are attributed to one or a combination of four factors: personnel, equipment, practices, and/or an unforeseen event. Once the cause has been identified, appropriate action is taken (Table 3), and all actions to reduce carcass contamination rates are archived for future reference.

## System Effectiveness

The on-line carcass monitoring system was implemented in June 1993. Carcass contamination for the three areas were reviewed four times per day, and a total daily rate was recorded. Average monthly carcass contamination was calculated for total carcasses and specific anatomical locations (Fig. 2). Initially, carcass contamination decreased from 7.6% to 5.3% of all carcasses. However, two months into the test, the contamination had reverted to 6.7%. The on-line monitoring system identified the evisceration stage as being primarily responsible for this increase, and an intensive training program was implemented. As a result, the total contamination rate decreased by approximately 3% within two months. Thereafter, the overall trend was downward, reaching 1.8% by November 1995. Despite a peak (3%) in February 1996, contamination continued to decrease, reaching an all-time low of 1.08% in October 1997.

Microbial data detailing the total aerobic bacteria, as colony forming units (cfu) per square inch of the carcass, were obtained for the first two and a half years of the project. Sponge (Nasco catalog B1245 WA, Fort Atkinson, Wis.) samples were obtained on carcasses immediately after the final carcass washer and before chilling. An area along the side of the belly was swabbed using a template (10 in × 2 in) and a sponge moistened with Butterfield's buffer. The belly area was chosen because of the ease of sampling and because studies indicated this area had bacterial levels similar to the shoulder, neck flap, and ham.

After mixing in a Stomacher 400 Laboratory mixer (Tekmar Co., Cincinnati, Ohio) and making dilutions as needed in Butterfield's buffer, the aerobic plate count was determined by pour plating with Standard Plate Count Agar (Difco Labs Inc, Detroit, Mich.). The plates were incubated aerobically at 35°C for 48 hr before manual counting.

Microbial contamination decreased consistently from an initial count of 4.8 to 2 $\log_{10}$ cfu/sq in (Fig. 3). Interestingly, analysis of these data showed a strong correlation ($R^2 = 0.88$) between visible carcass contamination and total plate count, demonstrating the practical benefit of the on-line carcass monitoring system in improving the microbial quality of the hog carcasses.

## Implications

Efficient and safe evisceration can be difficult to achieve, as it depends on a number of factors. These include the source of the hogs, feed withdrawal times (Miller et al., 1997), the skills of individual operators, and operator turnover. Indeed, the techniques used to eviscerate determine the extent of contamination of the carcass with fecal and ingested matter (Borch et al., 1996). Since the intestines of healthy pigs contain a variety of human pathogens, including *Campylobacter* spp., *Salmonella* spp., and *Yersinia enterocolitica* (Gill and Bryant, 1993), it is not surprising that the viscera-removal operations are a major source of these pathogens.

Despite recent improvements, carcass contamination rates still need to be decreased further. Epling et al. (1993) reported a 10% incidence of *Campylobacter* spp. and a 28% incidence of *Salmonella* spp. on pig carcasses. The incidence of swine carcasses which are positive for *Y. enterocolitica* can vary from low—2.1% (Rasmussen et al., 1997)—to high—24.7% (Andersen, 1988). Data for swine carcass surfaces from the Nationwide Pork Microbiological Baseline Data Collection

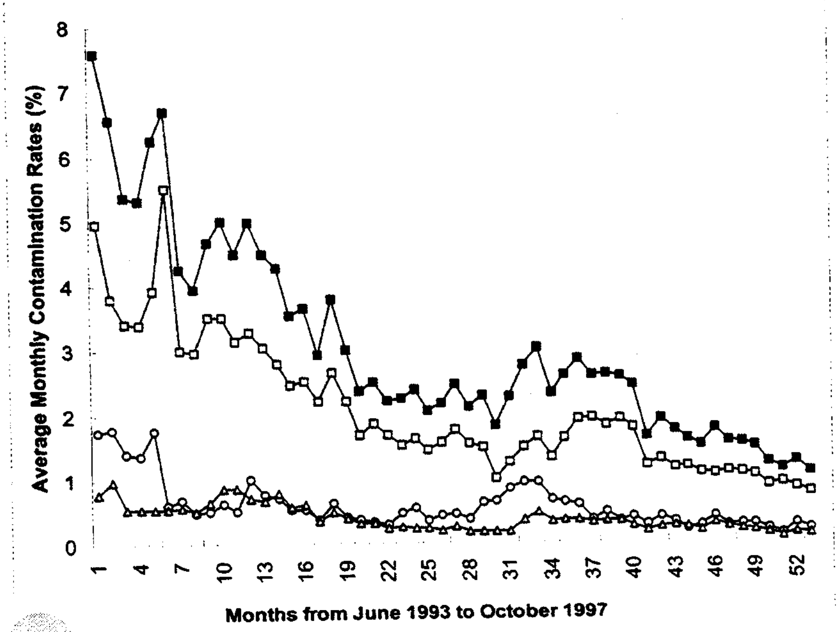


**Fig. 2—Average monthly percentages** of carcass contamination (■) and individual contamination at areas 1 (ham/tenderloin, O), 2 (rib cage/leaf lard, △), and 3 (breast bone, □) which make up this total

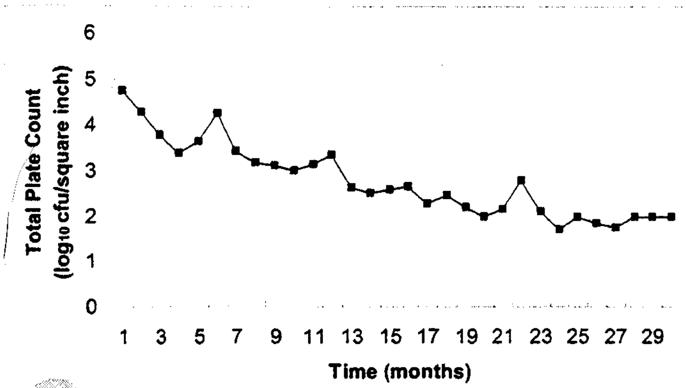


**Fig. 3—Average monthly total plate count** from June 1993 to November 1995

Program (FSIS, 1996b) show the following incidence: *Salmonella* (46%), *Campylobacter coli/jejuni* (21%), *Listeria monocytogenes* (48%), and *Staphylococcus aureus* (16%).

Training and educating employees about the importance of a specific job is needed to achieve the highest standards of performance. This is particularly important in the meat industry, where high employee turnover rates require greater efforts to maintain a well-trained and highly experienced workforce. In addition, employees need to be well motivated. This also presents a challenge to meat companies, where, in common with other large production-line industries, operators often repeat the same task several thousand times per day.

Integration of HACCP and TQM provides the best approach to improve safety and quality in the food industry (Anonymous, 1997). The on-line carcass monitoring system described here is an integral part of the company's HACCP program and has also been used by company management for the application of TQM principles. Employee responsibility, participation, input, and feedback have helped motivate operators in critical areas to continually improve their performance. In fact, competition arose among those working at the three operating stations.

Since there is no penalty against the individual worker who may have caused the contamination, fear has been replaced with a desire to do the job better. The net result has been an eight-fold reduction in carcass contamination rates, while microbial contamination levels have decreased by 99.8% and currently stand at less than half the U.S. national average of 4.5 $\log_{10}$ cfu/sq in (Anonymous, 1996b).

Implementing the on-line carcass monitoring system initially met with resistance from some employees, who did not wish to have their mistakes broadcast to their fellow workers. However, it was realized that the feedback provided could also be used to highlight skills and good performance, thus engendering job pride.

Once running, the constant feedback identified several other problems. These included personnel problems, which were solved by additional training; engineering problems, one of which required the debunging operation to be redesigned; and problems associated with the normal dressing practices used. A good example of the latter was the intermittent occurrence of bloated intestines, which resulted in a greater frequency of contamination events, due to the greater number being accidentally cut during removal. After consultation with producers about feeding regimes prior to slaughter and by increasing feed withholding times, this problem was also overcome.

The FSIS zero-tolerance policy for visible fecal contamination on carcasses has focused the meat industry on meeting the minimum regulatory standards to ensure that the carcasses are passed as fit for consumption, instead of focusing on safety and continuous improvement. The system described here shifts responsibility for producing a safe product to individual workers. By keeping the objectives and the message simple, and by educating employees as to the dangers associated with "dirt, bugs, and germs," regulations are met and carcass quality is improved, since less trimming is required. Indeed, implementation may decrease overall production costs, as less trimming results in the need for fewer personnel and less waste.

This system should also find application in other meat plants as an important tool in the drive to improve the microbial safety of meat products.

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